With H. B. Witton's compliments

SELENOGRAPHY.

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Except the sun itself, none of the heavenly bodies has attracted so much attention as the moon. Her apparent size and nearness to the earth, the subdued splendor of her light, her erratic course in the heavens, the rapid change and frequent recurrence of her phases, and the weird effect of her eclipses, have made the moon, from time immemorial, an object of intense interest. Literature, ancient and modern, bears witness to the truth of this. The Vaidie hymns shew that in the early dawn of Indogermanic civilization the phases of the moon were personified, and her influence was invoked with solemn rites. In many languages her name is given to one of the days of the week; this indicates how long she has been held in veneration, as Laplace has shewn names of the week-days are among the most ancient monuments of astronomical knowledge. Poetry, too, has thrown over the earth's satellite graceful veils of myth and fancy; while the most prosaic utilitarianism, in the interests of commerce, has been fain to do her honor. Pythagorus, in his system of cosmic harmony, credits the moon with contributing the highest note to the music of the spheres; and our own less imaginative forefathers, by such names as lunar caustic, selenite—thought to be moon-froth—and lunatic, have left a legacy to our vocabulary shewing their faith in the potency of the moon's influence.

In these latter days, that peculiar veneration the moon formerly commanded no longer obtains. The age of faith in her occult powers expired with the astrologer and alchymist, to be succeeded by an age of inquiry and knowledge which, rejecting the superstition of the old learning, still cherishes some measure of its devotion. Though we no longer plant and sow, herd our cattle, prune our vines, and gather in our harvests in awe of her sovereignty, yet our

lunar tables, nautical almanacs and observatories shew that the moon's influence is not yet ignored. In the sharp conflicts which have overthrown numberless ancient conceits, veneration for the moon did not utterly perish by the hand of the iconoclast, but in spirit still lives, transformed into the attention paid to her by positive science and investigation of her physical influence upon the world we live in.

Much that is noteworthy concerning the moon is inscribed so boldly on the firmament above us that the most listless observer cannot choose but read and be instructed. From the earth's axial rotation, both sun and moon have an apparent motion from east to west none can fail to notice. In addition to this apparent motion toward the west, common to all the heavenly bodies, observation of the star-sphere will shew that sun and moon proceed on a course among the stars toward the east. But that motion, though similar in direction, is otherwise different. One day with another the moon moves eastward about 13 degrees daily, making the circuit of the heavens in a month, while the sun goes towards the east but 1 degree each day, requiring a year to complete his circuit. Moreover, the eastward motion of the sun is apparent only, being caused by the earth's translation in her orbit, while the moon's eastward course is her proper orbital motion round the earth.

In her monthly course the moon, whose light is received from the sun, assumes various familiar phases. When in conjunction, nearest the sun, she is for a day or two lost in the sun's brightness. After such temporary concealment each month, she comes again to view—a radiant sickle in the western sky. The limb, or convex outline of the waxing crescent, is toward the sun. The horns of the crescent, and terminator, or dividing line between the bright and dark parts of the disk, are to the left hand of the beholder. Immediately before concealment the waning moon shews a reversed crescent having its limb toward the east, and its horn and terminator to the beholder's right hand. When half her monthly course is run, the moon in opposition becomes full moon. From new to full moon gradually the dark part of the disk ~~generally~~ becomes illuminated, and from full moon till the waning crescent is lost in the blaze of the sunlight, the illuminated part of the disk by almost imperceptible degrees becomes obscured.

In going through these phases the moon more than completes the circuit of her orbit around the earth, for the earth during a lunation is carried forward in its movement around the sun about 30 degrees, and the moon must pass over that distance before sun, moon and earth take the relative positions requisite to make new moon. Such a lunation, or course of the moon once round the earth, and far enough on a second course to come again in conjunction with the sun, is called the moon's synodical revolution. The mean time for making it is 29 days, 12 hours, 44 minutes and 3 seconds. The mean time it takes for the circuit of her own orbit only is but 27 days, 7 hours, 43 minutes and 11 seconds. Thus in each lunation the moon, from the earth's motion of translation round the sun, proceeds 2 days, 5 hours and 52 seconds on a second course before coming into the necessary alignment with sun and earth essential to present the phenomenon of new moon. These figures furnish the mean time in which the moon is carried through her orbit, but disturbing forces so considerably affect her velocity and direction, that astronomers, only by long profound research, have succeeded in foretelling what will be the moon's place in the heavens at any given future time.

Astronomical science regards the heavenly bodies in two aspects: in their relations to time and space, and as masses of matter moving in obedience to cosmical forces. Ages of observation prepared the way for the latter conception, and ancient astronomy chiefly kept watch over the times and seasons. Still, in the early stages of astronomical research, the moon was accorded attention, as many ancient nations used the moon's phases as a measure of time. The word moon, it is thought by some philologists, can be traced to the root *ma*, meaning to measure.

Although a lunation is, in many respects, a desirable standard for measuring time, it has been found extremely difficult to make it a sub-division of the tropical year or the time taken by the earth to complete her course from, and return to, the vernal equinox. Wherever the lunisolar year has been adopted intercalations have been necessary to bring the lunar months and solar years out even. The Greeks used simultaneously the two standards, and had no end of difficulty to keep them from overlapping. Their Olympiads supply a record for a thousand years, and are perhaps the best scale of past events on record. They originated from holding, every four years,

games at Olympia, at the time of first full moon after the summer solstice. For a long time Greecian months alternately comprised 29 and 30 days, but as a lunation is not the exact mean of these numbers, occasional corrections had to be made. The best known of such correctional devices, the cycle of Meton, covered a period of 19 years, 7 of which had 13 and the rest 12 months to the year, a total of 235 months for the cycle. One hundred and ten of these months had 29 days each, and the remaining 125 months of the cycle had 30 days to each month, making altogether 6940 days, 9 hours in excess of 19 tropical years, and 7 hours more than 235 lunations, leaving but a trifling discrepancy for future correction at the end of the cycle, between the three modes of reckoning time, by tropical years, calendar months and lunations. This cycle, called the golden number, because, it is said, the Athenians proclaimed it in figures of gold, is still used to determine the time of Easter, as ecclesiastical authority has decreed the Sunday following the first full moon after the Vernal equinox shall be observed as Easter Sunday. Thus modern Christendom and ancient Heathendom both accepted the moon as an indicator of the precise time for holding their great festivals.

Long years were given to the task of explaining the moon's motion. But modern astronomers have succeeded in shewing that motion accords with, and lucidly illustrates the principles of their science. The reasoning on which astronomical science depends is confessedly intricate, and its thorough mastery may well challenge the devotion of a lifetime. Nevertheless, it requires no special gifts or training to comprehend that the main links in that chain are: the conception of Copernicus that the earth has a daily axial rotation and an annual translation around the sun; and Kepler's laws—that a planet's orbit is an ellipse about its primary as a focus, that the areas swept by the radius vector of a planet are proportionate to the time of its motion, and that the squares of periodic times of planets are proportionate to the cubes of their distance from the sun. Add to these the discovery of Newton, which confirms them, that all bodies attract each other directly as their mass and inversely as the squares of their distance from each other, and we have the axioms on which the whole structure of modern astronomy is built. Kepler's generalizations were epoch-making. They compel all the more admiration that they were conceived in astrological times, and were

mixed up with astrological fancies. But Kepler, even in error, erred like a man of genius. When his feet took the wrong path, his face often turned toward the right. He believed the sun to have a soul, which was constantly rotating. He also thought that between sun and planets there is a friendly side, and a side that is hostile; and that when the friendly side was turned the planets moved toward the sun, and when the hostile side was turned they moved from him.

All this was fanciful enough, but here error pointed in the direction of truth, for twenty years later Galileo saw through his telescope that the sun's rotation was a reality. Newton's theory has withstood more than two centuries of criticism, and is confirmed by the most careful observations. Eight thousand telescopic observations taken of the moon during a period of eighty years were compared, under direction of Prof. Airy, with the place at which, by Newton's theory, the moon should be at the time of each observation. Each theoretical place was computed separately and independently. The work took a body of calculators eight years, at a cost of £4,300, and by it the truth of Newton's theory was fully sustained.

If the moon revolved around the earth, controlled solely by force of their mutual attraction, the calculation of her orbital motion would present no special difficulty to the expert astronomer. What would be the moon's position in the heavens at a given future time could be predicted with like exactness to that of Jupiter, which has been given ten years in advance, to within half a second of actual observation. But in addition to attraction of the earth, the moon is influenced by that of the sun, and to a less extent by that of the nearest planets. Moreover, from the moon's elliptic orbit and inclination of the plane of that orbit to the plane of the ecliptic, the sun's attraction is a force constantly varying both in degree and direction. Hence calculation of the lunar motion is one of the most difficult tasks accomplished in the field of physical astronomy. In a letter to Flamsteed, Newton himself lets fall words bordering on doubt as to whether he should finish the task. These lunar inequalities, as they are called, Prof. Airy explained in his work on "Gravitation." His book was written for general readers; and Lord Brougham, who tried his hand at similar work, deemed it the best account of the Newtonian philosophy ever written, or likely to be written.

Besides theoretical interest of being able to predict exactly the

moon's place in the heavens at any future time, toward the latter part of the 17th century, the more advanced governments of Europe recognized the great value such predictions would be to navigation. Increasing commerce with India in the east, and America in the west, made some exact method of determining longitude highly desirable, especially if it could be made simple enough for general use at sea. What was needed, and sought after, was to find the exact difference in time between two meridians, as the distance could then be readily enough known. The seaman could know from the sun's altitude the time at his meridian of observation, but it was at that day impossible for him to know at the moment of such observation the exact local time at his first meridian. To meet that difficulty two plans were suggested. One was to make accurate timekeepers not affected by ordinary changes of temperature, the other was to make the moon serve as a chronometer. To accomplish the latter task it was necessary to work out in advance at some first meridian the exact angular distance, at every hour, between the moon and some of the principal stars. By this means, when the seaman had taken the exact distance between the moon and a given star, simple inspection of his tables would shew him the exact time at his first meridian, when moon and star were the same angular distance apart as at his observation.

Charles II. was told in 1674, that such tables of lunar distances, worked out in advance, would be of great service to English seamen. The result was Greenwich Observatory was founded in 1675, and Flamsteed, who furnished his own instruments, was appointed "Astronomical Observator," at the salary of £100 a year. He determined with great accuracy the positions of about 3000 stars, and made a large number of lunar observations.

In 1714 the English parliament offered a reward to any discoverer of a method of finding the longitude at sea, the reward to be proportionate to the accuracy of the method found out. £10,000 was to be given if in a long voyage the method discovered approached absolute accuracy within sixty miles, £15,000 if within forty miles, and £20,000 if within thirty miles. Many methods were suggested. Some of these, as described in a letter by Flamsteed to his assistant, Sharp, were most absurd. The problem was at length solved by John Harrison, whose improved chronometers brought him, in

instalments, the maximum reward of £20,000. Harrison was a Yorkshire carpenter, who would have had little chance of success in a modern competitive examination; but his ingenious application of the different expansion by heat of two different metals to the construction of chronometers, was an inestimable service to his country and to the world. He made four or five chronometers. Of these, it is said, one was of such exactness that it did not vary a whole minute in ten years. Two of the Harrison chronometers are preserved at Greenwich Observatory. Sharp's biographer says: "A part of the escapement was, a few years since, removed from one of these, when the train of wheels ran down with velocity, though they had not turned for more than a hundred years."

In 1724, five years after Flamsteed's death, an Act of Parliament offered £5,000 reward for a set of tables giving lunar distances correctly to fifteen seconds of arc. Mayer, of Gottingen, worked out such a set, and sent them in 1757 to be tested, as, by terms of the Act, they had to be compared with actual observations for eighteen years and a-half. These tables were used in the Nautical Almanac first issued in 1767. Mayer died in 1762. His wife received the sum of £3,000, and Euler, a Swiss mathematician, was awarded a like sum. Euler's service was an approximate solution of the famous problem known as that of "the three bodies," namely: given their distances, velocities, masses and direction, what will be the path of one of three bodies around another, when all move in accordance with the law of gravitation? Hansen's lunar tables have since superseded those of Mayer. The British nautical almanac devotes six of its pages each month to lunar distances. They are now given to one second of arc, and are published three years in advance.

With what accuracy the position of a ship at sea can now be determined was exemplified a few years since by picking up the broken Atlantic cable from the bottom of mid-ocean. The cable was no larger in section than a ten cent piece; the buoys left to indicate place of the break were washed away, and nothing but his nautical skill was left to guide the navigator in what looked to be so hopeless a search. Yet with such extreme precision was the place of breakage recorded, and the searching vessel guided in her forlorn quest, that in a few hours the lost cable was successfully grappled.

Simultaneously with advancement of lunar investigation in the direction referred to, other observers were scrutinizing and mapping out the moon's surface. Without instrumental aid only a faint indication of the more prominent objects on the moon's disk can be seen, and it is not surprising these were long thought to be reflected images of the seas and continents of the earth. Galileo's "perspective glass," made by him about 1609, was the first known instrument by which the moon was seen more distinctly than by unaided vision. A year after Galileo made his glass he published an account of what he had seen through it. The quaint title of his book tells its own story. It reads in full: "The Sidereal Messenger, announcing "great and wonderful spectacles, and offering them to the consider-"ation of everyone, but especially of Philosophers and Astronomers, "which have been observed by Galileo Galilei, etc., etc., by the aid "of a perspective glass lately invented by him: namely, in the face "of the moon, in innumerable fixed stars, but especially in four "planets which revolve around Jupiter at different intervals and "periods with a wonderful celerity, which hitherto not known to "anyone, the author has recently been the first to detect, and has "decreed to call the Medicean stars." Galileo said that his first telescope made objects look three times nearer and nine times larger, and that he made a second, having a magnifying power of sixteen times. He probably never used an instrument which magnified more than thirty diameters. But by their use he constructed the first map of the moon ever made, and measured some of the lunar mountains. It is needless to add that Galileo immortalized his name by extending the boundaries of human knowledge, and by preparing the way for a more adequate conception of the infinite grandeur of the great Cosmos, the glorious universe of God.

A younger contemporary of Galileo, John Hovel (or Hevelius, as he was called in Latin, who was born at Dantzig) carried the work of lunar observation further than any of his predecessors. In his youth Hovel (whose father was a rich brewer) studied law, though mathematics and astronomy were his favorite pursuits. He travelled in Europe four years, attended in London the lectures of Wallis, one of the founders of the Royal Society, and would have visited Galileo in Italy, but was summoned home by his aged father to take charge of their brewery. But to astronomy he bent the best energies

of his life. He fitted up three contiguous houses owned by him, making them his observatory, workshop, engraving and printing office, and library. Hovel was an extraordinary man. He made his own instruments, engraved his own maps, and printed his observations with his own hands. On the 26th of September, 1679, a vicious servant wickedly sat Hovel's observatory on fire. Although most of his important works had been already printed and distributed, the loss of his instruments and many papers caused him much grief, and hastened his death. His "Selenography" appeared in 1647. The telescope he used magnified from thirty to forty diameters, and from his observations he engraved a map shewing two hundred and fifty lunar formations. The chief lunar formations he named after the earthly formations he fancied they most resembled. The lunar Alps and Apennines, and four of the lunar promontories, retain the names he gave them; and the term *Mare* used by him to designate the dark lunar plains has since remained in common use. He called these plains seas, he says ("*weil er sie mit nichts anderm besser zu vergleichen wisse*"), because he knew nothing better to liken them to. For more than a century Hovel's map was the best map of the moon.

The first telescopic observers soon found: the lunar hemisphere turned earthward is always the same, or nearly the same. The difference there is, is due to libration and its maximum amount is not a forty-ninth of the moon's circumference, or more exactly is 7 degrees, 53 minutes of lunar measurement. To that extent only the moon changes the face turned earthward. The rest of her sphere is hidden forever from mortal sight. Hovel was first to explain that libration in longitude is due to the fact, the moon rotates on her axis at a uniform rate, while her movement of translation varies in velocity with her varying distance from the earth. Galileo had already found out that there is a similar libration in latitude, due to the moon's axis of rotation not being exactly perpendicular to the plane of her orbit.

In 1651, J. B. Riccioli, a member of the Society of Jesus, compiled a lunar map noteworthy chiefly from its nomenclature. In lieu of Hovel's names, he designated the craters and places marked on his map after names of eminent mathematicians and astronomers. A French astronomer archly says: "Riccioli shrewdly avoided the

jealously of his contemporaries, by taking for his map only names of philosophers who were dead." His successors have marked his selections with approval, as more than two hundred of the names he chose are retained on lunar maps. For the great plains called by Hovel seas, Riccioli retained Hovel's names, but added others to them, intending thereby to indicate their supposed influence over the earth. This faint vestige of astrological conceits, if such it be, has not been obliterated from our maps. We still speak of the lake of death, sea of serenity, and the rest of Riccioli's fanciful names. But they have become meaningless. The belief which called them into being, namely: that the heavenly bodies influence human destiny, and that such influence in individual cases might be ascertained by protracted study, was once dominant in the world, but has faded away never to return.

Thirty years later Cassini published a lunar chart. He was a learned astronomer and a most indefatigable worker, and made important contributions to lunar knowledge. Lalande re-published Cassini's map in 1787.

About the middle of the eighteenth century, Mayer, whose lunar tables have been mentioned, proposed the publication of a more complete lunar map than had then been issued. He, unfortunately, died before his plans were carried out, though a map eight inches in diameter was published with his posthumous works in 1775. Although small, it was the most accurate map of the moon printed till 1824.

During the last quarter of the eighteenth century the elder Herschel, in England, and Schrœter, in Hanover, directed their attention to lunar investigations. They worked with better instruments than had been used by their predecessors, using magnifying powers from 150 to 300 diameters. Herschel, whose mechanical genius improved every astronomical instrument he touched, used micrometer measurements for his lunar drawings, instead of trusting entirely to skill of eye and hand. Schrœter's *Selenotopographische Fragmente* gave views of parts of the lunar surface with more details than any earlier map had given. He named many formations in the south-west part of the moon's disk, and sixty of his names are still retained. He first adopted the practice, still in vogue, of designating small spots near craters already named, by letters of the Greek and Roman alphabets.

In 1824, Lohrman, of Dresden, proposed to issue in twenty-five sections a lunar map 36½ inches to the moon's diameter; but, his sight failing, only four sections were printed. As Lohrman was a professional surveyor, and was assisted by the astronomer Encke, and used one of the celebrated telescopes made by Frauenhofer, of Munich, his work had rare merit, and is still referred to.

In 1834-6 appeared the map of the moon, by Beer and Mædler. It was on a scale of 3 ft. 2 in. to the moon's diameter, and was followed the next year by their great explanatory work—*Der Mond; oder allgemeine vergleichende Selenography.* Their labors carried lunar investigation far beyond the most advanced stages reached by their predecessors. Their book of more than 400 closely-printed pages, for exhaustive descriptions, and their map for minute details, won them unstinted praise, and still command the highest esteem. Later workers in their field of labor have employed more powerful instruments and made out details they failed to record, but their drawings and descriptions are still standards of authority, and are likely to remain such. Their mode of working shows the value of their work. To fix ninety-two chief points on the moon's disk, as bases for further measurements, they made nearly a thousand micrometric measurements from the limb of the moon. They also measured one hundred and forty-eight lunar formations with the micrometer. They made one thousand and ninety-five measurements of the shadows thrown by eight hundred and thirty different lunar mountains, minutely noting particulars of illumination at each measurement. From the length of these shadows the height of each mountain was carefully computed, and the resultant heights served as standards for determining the elevation of minor peaks whose shadows were projected under like conditions of illumination. They named one hundred and fifty lunar formations not named before, but made no innovations on the accepted nomenclature except that in carrying out Schrœter's plan of designating un-named craters by Greek and Roman letters they used Greek letters only for elevations, lower-case Roman letters for depressions, and Roman capitals for measured points. Their telescope was a Frauenhofer refractor of 8¾ in. aperture, having a magnifying power ranging from one hundred and forty to three hundred diameters. They worked chiefly with an aperture of 4½ in., and did not often use so high a power

as 300. As Lohrman had done before them, they followed Schrœter's system of describing by numbers the relative brightness of objects they observed. Their scale, since in common use, runs from zero for shadows to 10 degrees for the brightest lights.

Beer and Mædler's great work enjoys the reputation of being a model scientific monograph. Without trace of vanity or egotism, the workman in it is lost in his work. One of them, not content with his protracted labor on a difficult portion of the moon's disk, adds: *Quæ potui feci, faciant meliora potentes.* Involuntary one bows in respect to these plodding, sincere workers, as they say in conclusion: "The time and strength our labors have taken, make us aware this "is the chief work of our lives, but our toil will be rewarded if it "meet the expectations of the scientific world." Beer was a German banker, brother of Meyerbeer, the musical composer.

Schmidt, of Athens, for many years held a chief place of honor among observers of lunar phenomena. He made more than a thousand original drawings for a lunar map 75 in. in diameter. His map was completed more than thirty years ago, though publication was delayed from the question of cost.

In 1864, the British Association appointed a "Moon Committee," of which Mr. Birt was secretary. They decided to map the lunar surface on a scale of 100 in. to the moon's disk, and to use for that purpose a telescope magnifying 1000 times. It was decided to use preliminary sketch maps double the size of the map to be finally engraved. Some of the sketch maps were issued, but I am not aware that the finished map has ever been published.

Among English writers on lunar subjects, Nasmyth, the celebrated engineer who invented the steam hammer, is entitled to a high place. His book, "The Moon considered as a planet, a world, and a satellite," was issued in conjunction with Mr. Carpenter, and has run through several editions. It is much prized for its chapters concerning the physical condition of the moon, and for its exquisite drawings of lunar craters, mountains and plains. Nasmyth's exceptional skill in drawing never shone to more advantage than in his illustrations of lunar scenery. In his most interesting biography, Nasmyth describes his method of obtaining these illustrations. He first made, directly at the telescope, careful drawings of the part of the moon's disk selected for description. Full notes were taken with the

sketch as to illumination and other particulars to be kept in mind. The drawing, with its craters, mountains, rills, with all details of the part of the lunar surface adjacent, were next modelled in clay, and from the clay models, after they were dried and corrected by further telescopic observation, plaster casts were taken. These casts were then carefully illuminated to throw shadows similar to those projected by the objects when the drawing was made, and finally they were photographed. By such an unexampled expenditure of time and skill, were obtained those contrasts of light and shade, and delicate half tints, which make the Nasmyth lunar drawings so exquisitely beautiful.

To the instructive writings on lunar subjects by Webb, Elger and other popular writers, it is needless to refer. Nor need mention be made of the writings and eloquent addresses on these subjects by the late Prof. Proctor. His works speaks best for themselves to all who care for astronomical instruction.

The most complete treatise accessible to English readers concerning the moon is that published a few years since for Mr. E. Neison, F. R. A. S. Professedly based on the great work of Beer and Mædler, it has original merit, and not only includes his own observations for eight years, but those of Mr. Webb and other observers who aided him in his work, and also contains much interesting matter from the works of Schrœter and of Lohrman. His instruments were of the best class, and included a fine 6 in. refractor, and a 9½ in. With-Browning silvered glass reflector. The lunar map accompanying his book is in twenty-two sections, and is on a scale of two feet to the moon's diameter. Though his chart is more than third smaller than that of Beer and Mædler, it is finely engraved, shewing more formations than are given in their map, and more rills than are shewn by Schmidt in his "*rillen an dem Mond.*"

Neison groups the lunar surface under the names of plains, craters and mountains. His plains include all the large, dark, comparatively smooth tracts, called by the early selenographers *Maria*; the smaller tracts they named *Palus, Lacus, or Sinus*, and the brighter, smooth tracks which previously had received no name. For easy reference he divided the lunar craters into walled-plains, mountain-rings, ring-plains, crater-plains, craters, craterlets, crater-pits, crater-cones and depressions. His special names for the lunar mountains are great ranges, highlands, mountain-peaks, peaks, hill-

lands, plateaus, hills, mountain-ridges and land swells. These are arbitrary divisions, intended solely to shorten the printed descriptions and make them definite. To these groups are added the rills, or peculiar markings first noticed by Schrœter, that have somewhat the appearance of river-beds, but which some take to be fissures in the moon's crust. Several years since, Schmidt had a list of five hundred of these peculiar lines, and to present date that number is more than doubled.

Neison retains the names Beer and Mædler gave the four hundred and twenty-seven formations shewn on their map. To these he adds eighty-six others, making his map contain in all five hundred and thirteen formations. Each of these is described in the order of its place, and for easy reference an alphabetical list is also given. For every formation he cites the authority for its name and degree of brightness, and for craters and plains he gives their dimensions, and for mountains their height. The position in lunar latitude and longitude is given for each formation, in most cases to minutes, in some to seconds. Minute particulars are also furnished respecting parts of special interest, with name of observer and date of observation. Tables and formulæ to aid in computation are given, that the book may be of service to students desirous of engaging in original work. In proof of the merit of this book it was translated into German so soon as published.

Photography has been pressed into service for taking views of the moon. Dr. Henry Draper, of the University of New York, many years ago took excellent lunar pictures, using a silvered glass speculum he himself made, and mounted especially for taking lunar photographs. Prof. Rutherford, of New York, afterwards carried the art to still greater degrees of excellence; and although he had competitors in all parts of the world, a most competent judge, writing in the latest edition of the Encyclopædia Britannica, pays Mr. Rutherford the compliment of calling his the best photographs of the moon that had then been taken. During the decade just past, excellent lunar pictures have been taken at many of the great astronomical observatories in various parts of the world; those from Paris and from the Lick and Yerkes observatories being widely known and highly esteemed.

The field of lunar investigation is large, its laborers many, and

the task of lengthening the bead roll of discoverers already given would be easy and pleasant. But to add to this lengthy list were needless, if not wearisome. Moreover the names referred to fairly indicate the chief sources of positive knowledge concerning the moon, and the progressive efforts by which that knowledge has been obtained. There is a wide difference between the "perspective glass" of Galileo, which made the moon look nine times larger, and modern telescopes with magnifying powers of six thousand diameters. The optical part alone of a great modern instrument costs a handsome fortune, and its mounting and outfit of accessory instruments are costly, taxing as they do the resources of mechanical engineering and scientific skill. With such well equipped observatories, and the accumulated records of a century at command, one might suppose that knowledge concerning the moon would be nearly perfect. But science moves at a slow pace, and is more bent on gathering facts for inductions than in forming crude inductions from imperfectly ascertained facts. The man of science has to curb imagination tighter than in other days, and has le ned to speak on many subjects with more diffidence than did his predecessors. A hundred years ago the elder Herschel believed the moon to be inhabited, and after his time a learned man with an excellent telescope and keen vision—Gruithuisen, of Munich—wrote a scientific paper, entitled, *Entdeckung deutlicher spuren der Mondbewohner*—discovery of clear traces of the moon's inhabitants. It is not conceivable that such a paper could now be written in earnest. Since that paper was written such visionary notions have found little credence. The work of Beer and Mædler defined the legitimate boundary of lunar investigation.

An object 300 feet high and about a mile long is said to be approximately the minimum visible with a modern large refracting telescope, with usual low power ocular. With highest oculars, and best conditions of observation, a detached object, 40 feet high, projecting its shadow on a level surface might be perceptible. Beer and Mædler take 3⅓ English miles to be the extreme distance at which a person of keen, unassisted vision can distinguish an object 6 feet high, and estimate that it would require a telescope to magnify 51,000 diameters to shew such an object on the moon. Not much more than a tenth part of such magnifying power is at present avail-

able. The moon's disk subtends an angle of about half a degree, and mapping the lunar surface into 360 degrees of latitude and longitude, a lunar degree at the centre of the disk measures nearly 19 miles. Little that man has wrought on earth, could his most gigantic work be transferred to the moon, would attract much if any notice at the earth's distance, though if man's handiwork would pass unnoticed, no important lunar formation could now disappear or be materially changed, and elude detection. At the centre of the moon's disk, one second of arc equals 1.1585, more than one and a tenth English miles. What portion of the star-sphere a second of arc covers may be realized by calling to mind, a linear foot subtends a second of arc at 39 miles distance, and that the pole-star and its companion are 18 seconds of arc apart.

In the present stage of research there is divergence of opinion on many questions of lunar physics, though not more than might be expected from independent investigation. Bessel estimated the moon's atmosphere to be a thousandth the density of that of the earth, while Neison considers it to be greater than Bessel's estimate. Nasmyth, on the other hand, concludes that the moon is devoid of water, atmosphere and soil, and excepting contraction and expansion of the lunar crust from change of temperature, he thinks the moon now undergoes but little change. That there is great variation of temperature on the moon's surface from exposure for half a lunation to the sun, and from radiation of lunar heat into space for a like period admits of no doubt. The six foot speculum of Earl Ross' great telescope was, some years since, used for investigating the probable temperature of the moon. Earl Ross considered his researches tentative, and results approximate only. From his experiments and observations it was concluded that the difference between maximum and minimum temperature at the moon's surface is 200 degrees Centigrade. This difference in temperature between lunar mid-day and midnight was computed from measurement of the moon's radiant heat. This agrees in part with Sir John Herschel's estimate of the moon's climate. He writes: "The lunar "day is one of unmitigated burning sunshine, fiercer than an "equatorial noon, continued for a time equal to our fortnight, and "the lunar night is a period of the keenest severity of frost, exceed-"ing that of our polar winter, and of the same length as the "lunar day."